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ON A PECULIAR CLEAVAGE STRUCTURE RESEMBLING STRETCHED PEBBLES, NEAR ELLIJAY, GEORGIA[1]

W. C. PHALEN

INTRODUCTION

The subject of elongated or stretched pebbles has been treated in two articles by Mr. S. W. McCallie, state geologist of Georgia.[2] Both of the occurrences described are in Georgia, one of them, the first cited in the references below, being located in the vicinity of Ellijay, Gilmer County, about 75 miles north of Atlanta; the other 2½ miles southeast of Dahlonega, the county seat of Lumpkin County. Mr. McCallie's paper on the Ellijay occurrence may be summarized briefly as follows:

The stretched pebbles are chiefly confined to a belt less than one-half mile wide and about 15 miles long just west of the Louisville-Nashville Railroad and near the western margin of the crystalline rocks of the state. The beds containing the pebbles are in some places numerous. They vary from 1½ to 5 feet in thickness, and are always interbedded in mica schist. The pebbles in the different beds differ both in size and in degree of elongation. They are mainly found in a matrix of mica which, however, may be absent or nearly so, in which case the quartz pebbles may be welded together, requiring slight pressure to force them apart. Both quartz and feldspar pebbles are found, the former being the more numerous; the former also are greatly elongated while the feldspar pebbles retain more or less perfectly their original rounded shapes. The size, shape, color, and texture of the pebbles are next described, and the article closes with a description of thin sections of the pebbles. The title of Mr. McCallie's paper, "Stretched Pebbles from Ocoee Conglomerate," will serve to summarize sufficiently well his idea of the origin of the phenomenon.

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[1] Published with the permission of the Director of the U.S. Geological Survey.

[2] *Jour. of Geology*, XIV (1906), 55–59; *ibid.*, XV (1907), 474–78.

During the past three summers the writer has had opportunity to study the metamorphic complex in the Dalton, Ellijay, and Dahlonega quadrangles at the northern edge of Georgia east of the Great Valley. Stretched pebbles,[1] so called, have been observed at various places in the first two areas mentioned. Among the localities visited and studied is that near Ellijay depot, as well as others not very far away from the town. As a result of these studies a possible different interpretation of this interesting phenomenon has been deduced. It is the object of this short sketch to present evidence for this interpretation of a phenomenon which, so far as the writer is aware, has never been observed elsewhere than in the southern Appalachians, or at least has never been described from any other region.

GENERAL GEOLOGY

The portion of the Appalachian Mountain belt near Ellijay probably consisted formerly of both sedimentary and igneous rocks. The region has passed through one or more periods of dynamic metamorphism as a result of compressive forces acting from the east or southeast. During this metamorphism and possibly since, the rocks were profoundly folded and faulted; simultaneously with and subsequently to these structural changes they have been altered and mineralized and as a result almost perfectly recrystallized. The erosion and weathering characteristic of the region as a whole, which followed the earlier forces, has left them in their present condition. The character of the rocks in the region varies widely from slightly metamorphosed slate to profoundly crushed and metamorphosed igneous and sedimentary rocks.

Location.—The first occurrence of "stretched pebbles" to be described is located near the town of Ellijay, the county seat of Gilmer County, near the confluence of Cartecay and Ellijay rivers. The "pebbles" may be found in a cut not more than 20 feet deep, on the railroad, 100 yards more or less north of the depot, almost opposite and also just beyond the new wholesale house of W. J.

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[1] The term "stretched pebbles" is used for convenience in this and subsequent places. The writer's views as to the proper designation of these "pebbles" will be developed later.

Owenby & Co. This particular spot has been visited twice by the writer, first in the fall of 1907 and again two years later.

DETAILED GEOLOGIC RELATIONS

The cut is chiefly in the characteristic impervious surface or mantle clays of the region, and the "pebbles" are found in this clay, and in the slightly weathered country rock, found at the southwest end of the cut on the right side looking northeast. Those occurring in the country rock, however, are less perfectly developed than the others. The country rock is in the Great Smoky formation.[1] It is a greywacke and a weathered garnetiferous mica schist with the garnets largely altered to iron oxide. The schist is feldspathic. The rocks strike N. 20–45° E. and dip 50–60° S.E.

There are comparatively few or no signs of metamorphism in the rocks near Ellijay, which are extraordinary as compared with the general regional metamorphism, and such profound metamorphism as appears is generally quite local in development. At the location under discussion the rock has been so greatly crushed or subjected to such intense pressure that it does not break into massive blocks bounded by joint planes, but into long thin masses, resembling tapering lenses or stretched pebbles, overlapping when *en masse*, with excessive length as compared with their other dimensions. The illustration in Mr. McCallie's article[2] reveals the conditions well. At the south end of the cut these masses appear to be composed chiefly of quartz, and they will be found to crumble readily away from each other when removed from the ledge. When these quartz masses resembling stretched pebbles are thus separated, though some of the mica of the country rock falls away from them, considerable of it still adheres. Though many of these masses consist apparently of pure quartz, some of them contain or are largely made up of the micaceous portions of the country rock. All gradations between the two extremes may be observed. It is a fact, however, that the great bulk of the best examples of the "pebbles" are composed chiefly of quartz, excepting those produced from vein quartz to be described directly.

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[1] The same units have been chosen for mapping in the Ellijay quadrangle as were adopted by Keith in the Nantahala area to the north ("Nantahala Folio, No. 143," *U.S. Geol. Survey*, 1907). Of course the same scheme has not been adopted in its entirety, for the obvious reason that some of the more marked lithologic types die out in passing to the southward.

[2] *Journal of Geology*, XIV (1906), 56.

Traversing the country rock in all directions are quartz veins, true chemical segregations. Though formed subsequently to the rock in which they are found, they antedate, in this restricted locality, the period of metamorphism in which the pebbles described above were produced, for the reason that the structure has been produced in the quartz vein itself. Indeed it is from such material that the most perfect "pebbles" were obtained (see Fig. 1). The quartz veins in the railroad cut vary from a fraction of an inch up to 6 inches or more in thickness. Toward the northwest end of the cut under discussion, and just before the gradual curve to the right begins, will be found the best exhibition of the "pebbles." In the fall of 1907 one of the quartz veins could be traced fairly well across the cut, which at the time was thought to have furnished the bulk if not all of the best specimens. This evidence, however, is not at all conclusive at the present time, for on a more recent visit in the fall of 1909, this tracing could not be made at all, on account of slides in the clay in the cut. That the vein quartz has furnished the material for many of the lenses of "pebbles," however, can be shown from the specimens collected at the earlier visit, in which the gradation from the latter into the former is well brought out (see Figs. 2 and 3). In such hand specimens the quartz lenses may be picked out and replaced in their former positions, the whole appearing as a single solid mass when bound with an elastic band. Specimens were col-

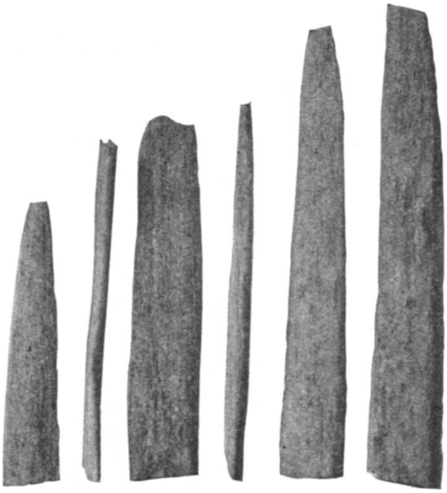

FIG. 1.—A group of quartz lenses, resulting from pressure on vein quartz. Ellijay, Gilmer County, Georgia.

lected showing varying stages in the transition from the unfractured massive vein quartz to those in which the quartz pebbles were fairly well developed. Such specimens though less perfect examples of the structure itself are nevertheless instructive in that they show the intermediate steps in the transition of the massive rock to the lenticular or stretched pebble-like phase, and one method by which the latter may be formed.

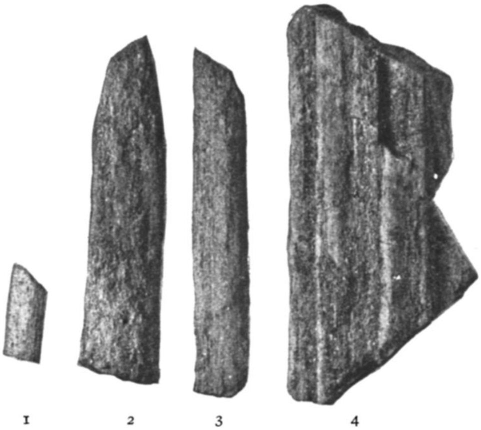

FIG. 2

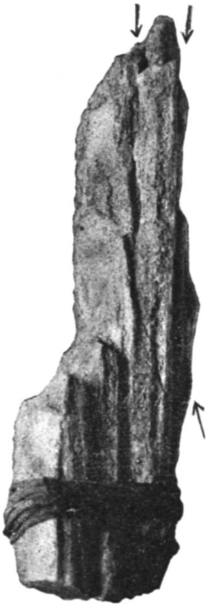

FIG. 3

FIG. 2.—Group of quartz lenses. Lenses numbered 1, 2, and 3 have been separated from 4 and may be replaced in their former positions.

FIG. 3.—A bundle of imperfect lenses. The arrow indicates a lens about to break off.

OTHER OCCURRENCES

On the road which leads directly north from Ellijay up Ellijay River there is another occurrence of the structure (for such it may be regarded) described near Ellijay depot, about a mile and a quarter north of the town and about a quarter of a mile south of the road forks.

The rocks here strike N. 20–25° W., though the general strike of the region is to the east of north. Like the rocks at Ellijay depot, the country rock here may be classed as a feldspathic mica schist, in which there are secondary feldspar phenocrysts, badly weathered. The rock probably was arkose originally. As at Ellijay depot, there are associated quartz veins which here however postdate the metamorphic processes which produced the pebble-like structure, as the vein material does not show any particular tendency to break into lenses as at Ellijay depot. The phenocrysts of feldspar already referred to have probably formed since the crushing took place, as during their development they have pushed away the surrounding matrix which now curves about them. This latter hypothesis to the writer is a more plausible assumption than that the crushing processes have failed to affect them, for there is no reason to suppose that they would resist the crushing action more effectively than quartz. The joint planes in the rock cut squarely across the pebble-like quartzes and are therefore in part at least of later origin. The broadest band in which quartz lenses appear is fully 15 feet thick. A short distance farther up the hill are two thinner bands showing the phenomenon equally well with the 15-foot band, and the intermediate beds exhibit it, though less perfectly. Such highly metamorphosed bands are fairly common in this general region and good examples have been observed and specimens showing the structure collected north of the head of Kells Creek within the Ellijay area.

It is not so easy here to disprove the former existence of original true quartz pebbles and no attempt will be made to do this. It will simply be pointed out that the similarity of the occurrences to that near Ellijay depot is noteworthy, and that, as in the latter case, another hypothesis for the origin of the quartz masses is not only possible but probable.

DETAILED DESCRIPTIONS

It was thought that a study of thin sections of the rock showing the pebble structure might throw some light on the origin of the phenomenon. The results, however, are somewhat inconclusive. The sections of the "pebbles" do show evidence of profound crushing, but then either crushed true pebbles or vein material would exhibit similar features in thin sections. Instead of the crystalline outlines characteristic of ordinary uncrushed vein quartz in thin sections (see Fig. 4), the sections are fine-grained mosaics with crystallographic boundary planes entirely absent (Fig. 5). Therefore the most important evidence of derivation from former vein material is absent. Even all signs of internal strain are lacking for the reason that the quartz like all the other rocks of the region has undergone almost perfect recrystallization, that is, molecular readjustment to the surrounding conditions. The actual tracing of the "pebble" structure, however, into the original quartz vein material is sufficient evidence for another explanation of the phenomenon.

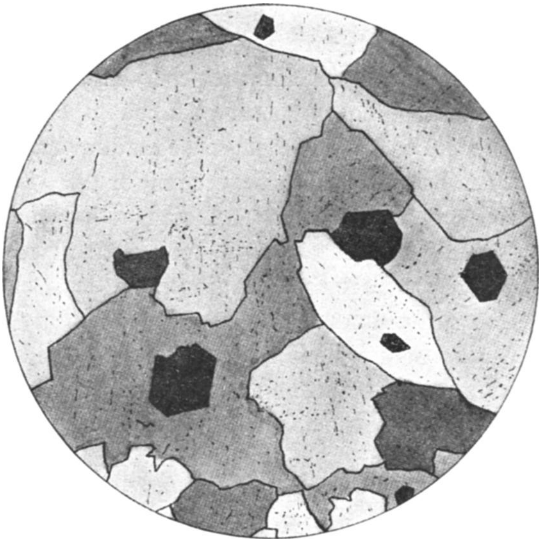

FIG. 4.—Normal structure in vein quartz. From the report of Waldemar Lindgren on the "Gold Quartz Veins of Nevada City and Grass Valley Districts, California." In *Seventeenth Annual Report, U.S. Geological Survey*, Part II (1896), Pl. IV, Fig. *a*, opposite p. 132.

The results of the examination of the thin sections are given below.

Several thin sections cut in various directions from the quartz masses were studied in polarized light under the microscope, to determine if possible how deformation took place. These sections were cut as follows: (1) normal to the direction of elongation of the pebbles; (2) parallel to the direction of elongation and to the major axis of the approximately elliptical cross-section; (3) parallel to the direction of elongation and to the minor axis of the approximately elliptical cross-section.

The sections are all alike in showing the quartz masses to be essentially mosaics of irregularly shaped granular interlocking particles. In a word, the microscopic structure is typically that of crushed and recrystallized quartz. In the first set of thin sections examined, namely, those cut normal to the direction of elongation of the masses, the grains show dimensional, but not crystallographic parallelism. The longer axes of the grains, as would naturally be supposed, are parallel to the major axis of the elliptical cross-section. This may be and quite likely is due to deformation, but there are no evidences of deformation in sections cut parallel to the direction of elongation of the quartz masses, as might naturally be expected. If due to deformation producible by pressure normal to the direction of flattening, all evidence of internal strain, usually evidenced by wavy extinction, has disappeared, but this might readily be brought about by recrystallization. The perfect interlocking of the grains is

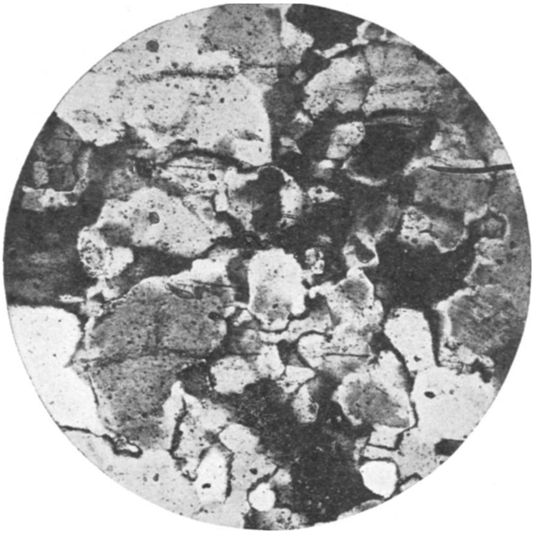

FIG. 5.—Micro structure of crushed vein quartz from near Ellijay, Ga. The lack of crystallographic boundaries is apparent.

evidence of recrystallization. The molecular readjustment necessary to obliterate all traces of strain may have occurred while the rock was deeply buried, for it is almost certain that many of the phenomena associated with the rocks of the region could only have been produced while under very heavy load, i.e., while deeply buried, or subjected to great pressure, or both. But it seems that recrystallization by solution and redeposition is as adequate and as safe an explanation. That the rocks contained water is certain. The presence of muscovite and biotite as secondary minerals, and the evidences of the sedimentary origin of the rocks, all point to the former presence of water. The amount of water present may have been small, as the presence of large quantities of water to bring about such molecular changes as postulated above is not essential.[1]

In sections cut parallel to the length of the quartz masses, there are also evidences of crystallographic continuity, the larger part of the sections extinguishing in a given position. Finally in all the sections studied cracks were observed running parellel to the major axes of the cross-section and also parallel to the length of the quartz masses.

CONCLUSION

As a result of the studies made by the writer, it is concluded that there is no necessity for assuming the former presence of original quartz pebbles to produce the pencillate or pebble structure, or lens-shaped masses of quartz described above, for, as pointed out, the more perfect examples of the structure have been found resulting from quartz veins. That elongations in true quartz pebbles may occur and the results exactly resemble the structures figured above, is so obvious as hardly to necessitate mentioning here. The structure is regarded as essentially due to a peculiar cleavage combined with flow cleavage (recrystallization). It is quite likely that it may be produced in any rock and the simpler, the more resistant, and the more homogeneous the material, perhaps the more perfect the resulting structure. Such structures on a much larger scale have been observed by Mr. Arthur Keith of the U.S. Geological Survey, a few miles west of Canton, Ga. They are figured in the accompanying illustration (Fig. 6). The country rock here is a talc schist, and

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[1] C. K. Leith, "Rock Cleavage," *Bull. U.S. Geol. Survey, No. 239* (1905), 69.

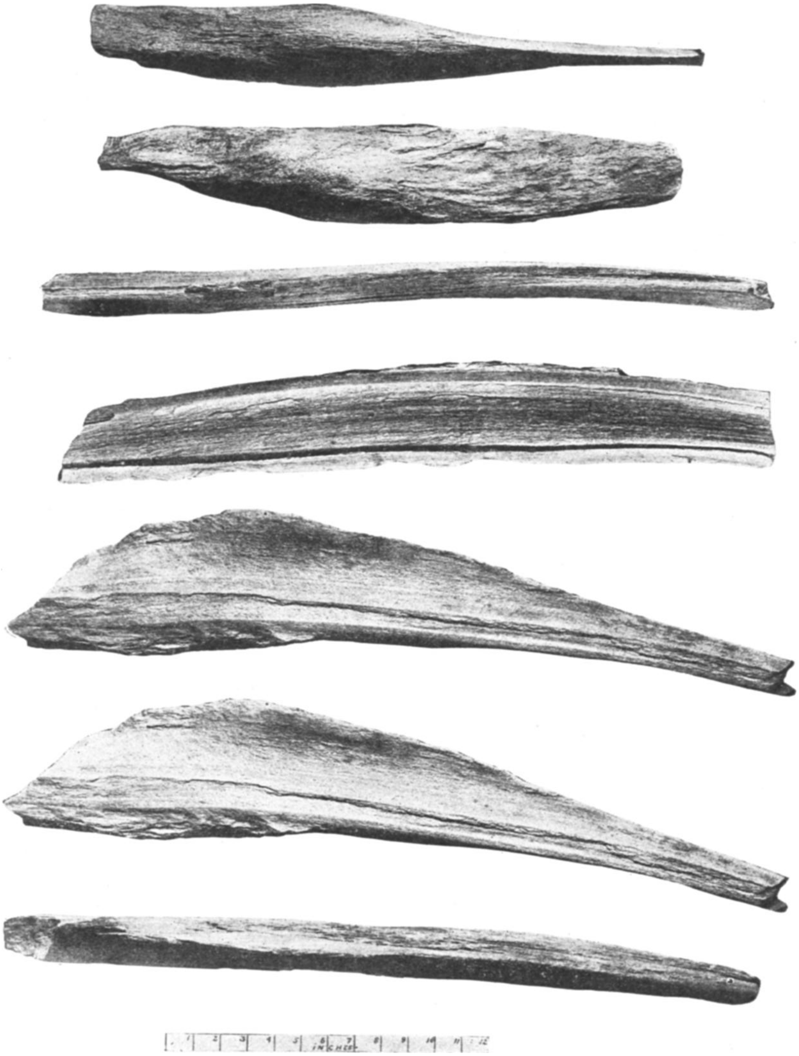

FIG. 6.—Elongated or lens-shaped masses of quartz, occurring in talc schist. Photograph of specimens collected by Mr. Arthur Keith, U.S. Geological Survey, near Canton, Georgia.

the elongated lens-shaped masses are essentially made up of quartz with an outer covering of the schist. They measure nearly 3 feet in length, with a breadth of 2 to 4 inches and a thickness of 1 to 2 inches. So far as appearances go, they closely simulate on a much larger scale the smaller masses collected near Ellijay. They cannot by any stretch of the imagination be regarded as stretched or deformed bowlders. Pogue[1] has figured and described almond-shaped masses of mashed acid coarse tuff from Davidson County, North Carolina. The rock, according to this writer, has undergone a moderate amount of compression and now projects above the ground surface in lenticular or almond-shaped masses 20 feet long, 10 feet high, and 5 feet thick at the base. They are distributed in groups and often scores may be seen in alignment following the trend of a tufaceous belt. It has occurred to the writer that Pogue's almond-shaped masses may be of the same nature as the structure observed near Ellijay, but on a gigantic scale. In conclusion, it is desired to emphasize the view that the Ellijay occurrences are purely structural phenomena producible in varying degrees of perfection in almost any rock, independent of original pebbles, and liable to occur in any region of intense metamorphism.

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[1] *Am. Jour. Sci.*, XXVIII (September, 1909), 224.